# Controls on Low-Cloud Cover in Simulated Climate Change

Xin Qu, Alex Hall
University of California, Los Angeles

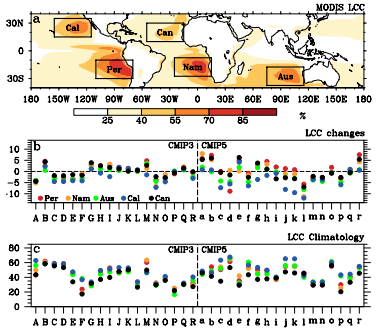
Stephen A. Klein
Lawrence Livermore National Laboratory

## Introduction

Climate sensitivity varies a lot between models because low clouds predictions for marine stratocumulus regions differ. In this study, we explore why models differ by considering how clouds respond to environmental boundary conditions (i.e., the strength of the inversion capping the atmospheric boundary layer, and sea surface temperature) and greenhouse gas concentration in the current climate.

## Simulated Low-Cloud Cover Changes

Low-cloud cover (LCC) is defined as clouds below 680 hPa. Random overlapping is assumed to obtain the overall cloud cover from cloud cover at multiple sigma levels.




**CMIP3**
**20th-century and scenario A1b runs:**

A – BCCR-BCM2.0
B – CCSM3
C – CGCM3.1(T47)
D – CGCM3.1(T63)
E – CSIRO-Mk3.5
F – ECHAM5/MPI-OM
G – FGOALS-g1.0
H – GFDL-CM2.0
I – GFDL-CM2.1
J – GISS-EH
K– GISS-ER
L – INGY-SXG
M – INM-CM3.0
N – IPSL-CM4
O– MIROC3.2(medres)
P– MRI-CGCM2.3.2
Q – PCM
R – UKMO-HadCM3

**CMIP5**
**20th-century and RCP 8.5 runs:**

a– BCC-CSM1.1
b – CCSM4
c – CSIRO-Mk3.6
d – CanESM2
e – FGOALS-s2
f – GFDL-CM3
g – GFDL-ESM2G
h – GFDL-ESM2M
i – GISS-E2-R
j – HadGEM2-CC
k– HadGEM2-ES
l – IPSL-CMSA-LR
m – MIROC-ESM
n – MIROC-ESM-CHEM
o – MIROC5
p – MPI-ESM-LR
q – MRI-CGCM3
r – NorESM1-M

### Heuristic Model

EIS change · SST change · $CO_2$ change

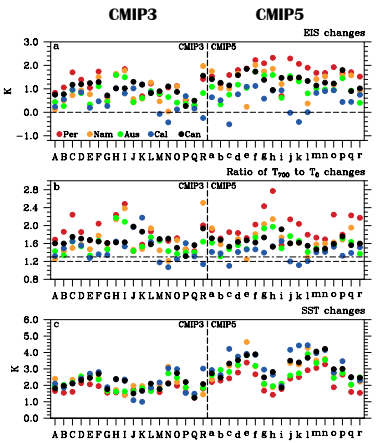
$$\Delta LCC = \frac{\partial LCC}{\partial EIS}\Delta EIS + \frac{\partial LCC}{\partial SST}\Delta SST + \frac{\partial LCC}{\partial \log(CO_2)}\Delta \log(CO_2)$$

EIS slope · SST slope · $CO_2$ slope

where $EIS = LTS - \Gamma_m^{850} \bullet (z700 - LCL)$. In this equation LTS is lower-troposphere stability, Gamma is the moist-adiabatic potential temperature, z700 is the height of the 700 hPa surface and LCL is the lifting condensation level.

EIS, SST and $CO_2$ slopes are calculated based on climate variability in the past 100 years (1913-2012). EIS, SST and $CO_2$ changes are calculated as differences in the respective quantities between the periods 1913-2012 and 2080-2099.

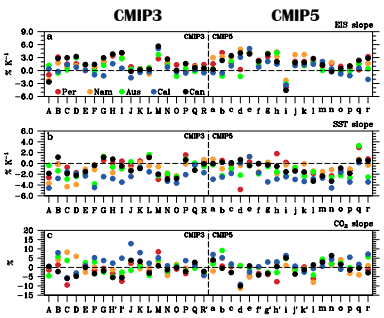
## EIS and SST changes




1. EIS changes are generally positive, suggesting that there is an increases SST gradient between the warm pool and the marine stratocumulus regions

2. EIS and SST changes vary with regions and models.

## EIS, SST and $CO_2$ slopes

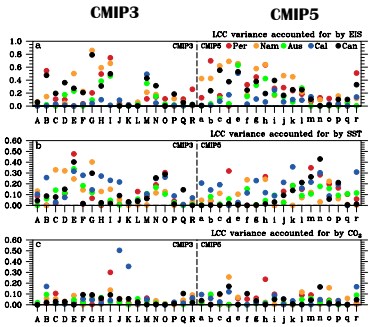



1. EIS slope is generally positive, indicating increasing LCC with increasing EIS.

2. SST slope is generally negative, indicating decreasing LCC with increasing EIS.

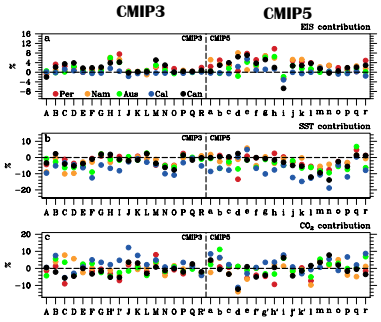
3. CO2 slope is very variable across regions and models.

## LCC variance accounted for by EIS, SST and $CO_2$

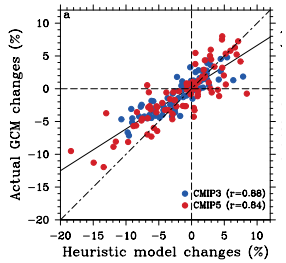



LCC variability in the past 100 years is dominated by EIS and SST processes and the $CO_2$ effect is small.

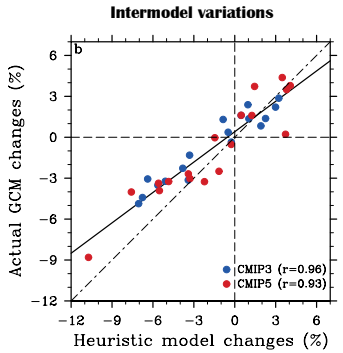
## The respective contributions of EIS, SST and $CO_2$ to LCC changes



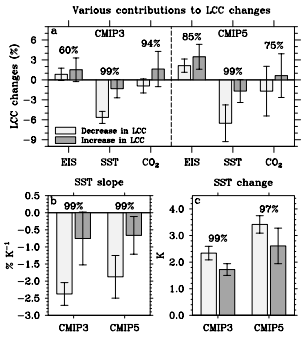

## Heuristic model captures actual GCM LCC changes




**5 regions and 36 models**




## Factors modulating the sign of LCC changes




Both SST slope and change modulate the sign of LCC changes.

## Summary

- To understand simulated LCC changes, we develop a heuristic model, in which the effects of EIS, SST and $CO_2$ changes are quantified. The sensitivities of LCC to these three quantities are estimated based on climate variability in the past 100 years.
- The effect of EIS is generally positive, while the effect of SST is generally negative. The effect of $CO_2$ is highly variable across regions and models.
- Case studies using models with large LCC increase or decrease suggest that both SST slope and change are important modulators of the sign of LCC changes.

## Acknowledgements

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